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IRRIGATION ON STEEP LAND

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Although most irrigated crops are produced on the flatter valley lands, considerable use is also made of foothill and mountainous areas for the production of irrigated crops in California. The selection of the correct method of irrigation to use for each set of conditions is essential to obtaining the most efficient use of our soils and water resources. This publication describes different types of irrigation methods that are being used on steep lands. After the grower has selected the method which will best satisfy his needs, he should obtain a detailed design before starting the installation of his irrigation system. Such designs can be obtained from consulting engineering firms or from some equipment dealers.

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IRRIGATION ON STEEP LAND[1]

PROPER IRRIGATION MEANS WATER AND SOIL CONSERVATION AND BETTER CROPS

Proper irrigation of steep lands helps to prevent the waste of water and erosion of the soil. It also permits application of the water in correct amounts at the right times to provide the crop with a continuous supply of readily available soil moisture. The result of careful water use is better crops at less cost.

The two methods most generally used for applying water on steep land are surface irrigation and sprinkler irrigation; a third, the trickle (drip) method is also gaining considerable interest. Examples of different ways of using these three methods are illustrated and discussed herein.

To select the method which will best fit the conditions of your farm, you need to consider:

Slope of the land

This is the number of feet of vertical rise or fall of the land surface in 100 feet of horizontal distance—generally expressed as per cent. Lands with slopes greater than 2 per cent are generally considered to be steep. The amount of care required for controlling the irrigation water increases as the slope increases.

Soils

Most steep lands are shallow and may be underlain by bedrock, hardpan, or a clay layer at a depth of 2 to 4 feet. On such soils, the downward movement of the soil water is impaired, and over-irrigation can result in saturating the soil. This reduces the supply of oxygen needed by plant roots and can create an unhealthy environment for the roots. Excess water will seep to the base of the slope and may create a waterlogged soil condition and death of the crop in that area.

Soils that shrink and form deep cracks upon drying are difficult to irrigate by surface methods. Water entering the cracks moves down the slope, often causing serious erosion. Such conditions make it difficult to control the water while irrigating.

The amount of available water that can be retained in a soil for use by plants is related to the soil texture (size of the soil particles). A clay or silt soil will hold more usable water in each foot of depth than will a sandy soil. The depth of available water that can be stored in a foot depth of soil will vary from ½ to ¾ inch in sands, ¾ to 1½ inches in loams, and 1½ to 2½ inches in clays. The sandy soils, therefore, require lighter irrigations at more frequent intervals than do the heavier textured soils.

Some soils are more erosive than others. Sand and silt soils often do not form water-stable aggregates needed to hold them in place, and they may be carried down the slope with the water. Extreme care in applying irrigation water to erosive soils is needed. Cover crops are often planted in orchards and vineyards grown on steep land to help resist erosion of the soil.

Soils also vary in the rate that applied water will infiltrate into the soil. The intake rate for water may be less than $1/10$ inch per hour for some clay soils. Most loam soils will absorb water at a rate less than ⅓ inch per hour over an extended period of time. Sandy soils, with large

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pore spaces, will usually absorb water at a rate of ½ inch per hour or more. The irrigation water must be applied at each location for sufficient time to allow the desired depth of water to enter the soil. For example, to apply a 2-inch irrigation to a soil with an intake rate of 0.2 inch per hour will require an intake opportunity time of 10 hours for the 2-inch irrigation to be absorbed by the soil. Applying the water at a faster rate than the soil can absorb it will result in surface runoff, waste of water, and soil erosion.

Water supply: quantity and quality

Water obtained from an irrigation district or water company may be delivered to each farm on a rotation, continuous flow, or demand basis. The grower should determine which method of delivery is available in his area before planning his irrigation system. Where water is obtained from a well, the pump can be designed to fit the particular irrigation system on any farm, providing an adequate flow of water is available from the well.

The total salt content, the amount of sodium, and the presence of toxic minerals such as boron in the water should be considered. If the total salt content is high, occasional leaching of the soil will be required. Some plants, such as citrus, will absorb sodium or chloride through the leaves. Water containing more than 3 me/l of sodium or chloride should not be sprinkled onto the leaves of such plants. The leaf absorption of sodium or chloride will result in leaf burn and sometimes defoliation. Waters high in sodium may cause the soils to seal unless gypsum is added.

Crop

Rooting depths of various crops will vary with the type of plant and its age. Mature trees and vines will normally develop roots to depths of 8 feet or more in the soil. Annual plants have an ever-expanding root system which will penetrate the soil to depths of 4 feet or more, when the plants reach maturity. The rooting depths may be limited, however, by soil profile conditions, such as claypans, sand stratas, saturated soils, or shallow depths to bedrock. Trees and vines extend their roots laterally, and at maturity, they will utilize the entire soil area between plantings. The depth and extent of plant roots must be known in order to plan an irrigation program for any crop. The water-holding capacity of the soil and the depth of rooting determine the total amount of available water that can be stored in the soil.

Amounts of water used by plants will depend upon the leaf area exposed to sunlight, the amount of solar radiation, the air temperature and humidity, and the amount of wind. These factors will vary for each location, for each season of the year, and for the type of crop being grown.

The irrigation system must be adequate to satisfy the peak water needs of the plants. The period of peak water use in California normally occurs in midsummer. Peak use for the different areas within the state is as follows:

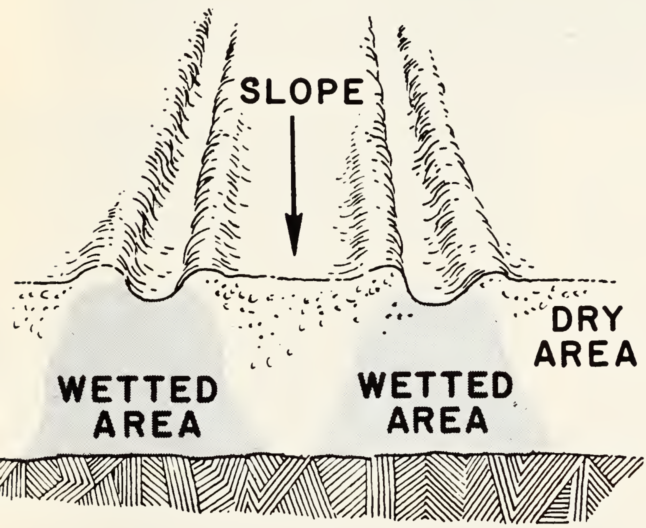
Area	Water use per day	Equivalent continuous flow
	Inches	*gallons/minute/acre*
Coastal fog belt	0.10–0.15	1.9–2.8
Coastal valley	0.20–0.25	3.7–4.7
Interior valleys	0.25–0.30	4.7–5.6
Desert areas	0.35–0.40	6.5–7.5

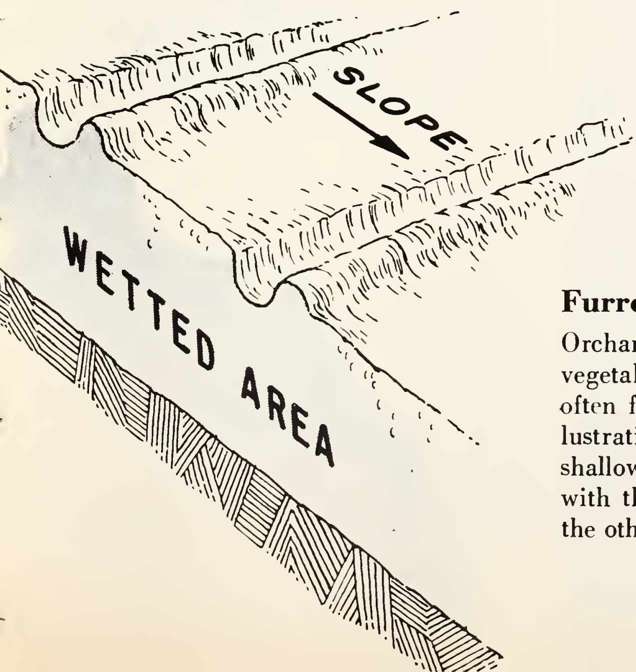
The equivalent continuous flows shown must be increased accordingly when the irrigation system is operated only part of the time. An irrigation system which is designed for continuous operation to satisfy the peak-water requirement of a crop will only need to be in operation part of the time during the cooler seasons of the year when the water requirements are less.

The seasonal irrigation requirements of crops are related to the time of the year when the crop is being grown and the

climatic conditions at the location where the crop is planted. Crops grown in areas of high rainfall will have a lower seasonal water requirement than will the same crops grown in areas of low rainfall. Young plants which have not developed a full leaf cover will use less water than will mature plants. However, young plants also have a limited root system and so will require more frequent, lighter irrigations to maintain an available supply of soil water than will mature plants. Irrigation requirements may vary from 12 to 48 inches depth of water a year for various crops grown in different areas in California. Your county farm advisor can supply you with estimates of monthly water requirements for different crops.

SURFACE IRRIGATION





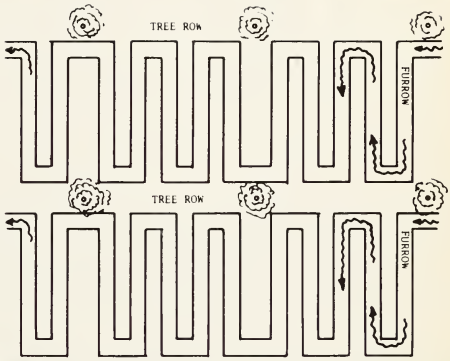
Furrow irrigation

Orchards, vineyards, strawberries, and vegetable crops planted on hillsides are often furrow-irrigated. These are two illustrations of the wetting patterns in a shallow soil irrigated by furrows—one with the water running down the slope, the other across the slope.

This mature orange orchard has been terraced with the trees planted on the outer edges of the terraces where the soils are the deepest. Permanent furrows have been placed between the tree rows. A buried concrete pipeline conveys the water down the hillside with hydrant outlets spaced at every tree row. Metal gated pipes deliver the water from the hydrants to the furrows on the steeper areas; while on the flatter areas, the water flows directly into the furrows from the hydrants.

This cucumber planting is irrigated by furrows placed across the slope. A wooden V-flume conveys the water down the slope. Holes drilled in the side of the flume provide outlets for the water into the furrows. Small boards which pivot on a nail are used for controlling the flow of water into the furrows. Plastic films along the plant rows protect the cucumbers from wind damage.

Contour furrows are being used to irrigate these staked tomatoes in San Diego County. Two furrows are placed between the plant rows. The young tomatoes are being irrigated by the furrow on the uphill side of the plants. The furrows are usually installed with a slope of about 1½ feet of fall per 100 feet. The water is delivered to the furrows through a gated pipeline. Slide gates regulate the amount of water released into each furrow.



"Zig-zag" furrows are sometimes used in orchards or vineyards to decrease the slope of the furrows by increasing the distance the water must travel. Special furrowing tools with blocking devices which can be operated with tractors are available for forming the furrows. By decreasing the slope, the velocity of the water is slowed down. This reduces erosion, increases water depth in the furrows, (which, in turn, helps to increase water penetration into the soil). The furrows may be permanent where nontillage practices are used; however, the usual practice is to disk the soil for weed control and reconstruct the furrows several times each season.

Strip checks

For irrigating pastures on hillsides with slopes up to 7 per cent, earth levees are constructed at intervals of 12 to 20 feet to guide the water as it moves down the slope. The strips are in the direction of steepest slope to provide a minimum of cross-slope between adjacent levees. The strips should have a slope of at least 0.3 foot per 100 feet in the direction the water flows to provide drainage of excess surface water from the pasture. The irrigation water is delivered to the strips through a buried concrete pipeline placed across the upper edge of the field. Orchard valves placed in concrete risers attached to the pipeline regulate the flow of water into each strip. (Further information is available on this method of irrigation in "The Border Method of Irrigation," Circular 408, University of California Agricultural Experiment Station.)

The waste water running off the pasture can be collected in a sump at the lowest corner of the field. This water can be reused for irrigation by pumping it back to the head edge of the field through a return flow system. For further information about this practice, see "Irrigation Return-water Systems," Circular 542, California Agricultural Experiment Station.

Wild flooding

Rough, rocky, steep land that is not suitable for strip-check irrigation can be irrigated only by wild flooding or sprinkling. A supply ditch is placed across the upper edge of the field. This ditch should have a slope of 6 inches per 100 feet of distance. The usual method of construction is to plow along the line of the ditch, then shape it with an angle blade on a light tractor. The ditches are sometimes lined with concrete to prevent soil erosion, loss of water, and reduce the amount of cleaning. Water is spilled from the ditch by overflowing the banks, or turnouts can be spaced at 6- to 10-foot intervals. The turnouts are made by shoveling breaks in the bank. Placing rocks or lumps of sod for the crest and sides of the turnouts helps to prevent erosion. Pickup or spreader ditches are constructed at intervals below the supply ditch to redistribute the water as it flows down the slope. These can be placed at locations where water tends to collect. The usual practice is to have these at 50 to 100 foot intervals. Turnouts along these ditches are similar to those on the supply ditch.

When properly used, sprinkler systems provide an excellent method of controlling the application of the water. Factors to consider:

1. Distribution of water should be nearly uniform over the entire area being irrigated.
2. Precipitation rate of the water should be less than the infiltration rate of water into the soil. Otherwise, runoff will occur resulting in waste of water and possible serious soil erosion.
3. The system should be adequate to supply the amount of water needed to satisfy the peak water requirements of the crop.
4. The costs of installing and operating the sprinkler system must be economically feasible so that the income from the crops produced will bring a net return to the grower.

Hand-moved portable pipe

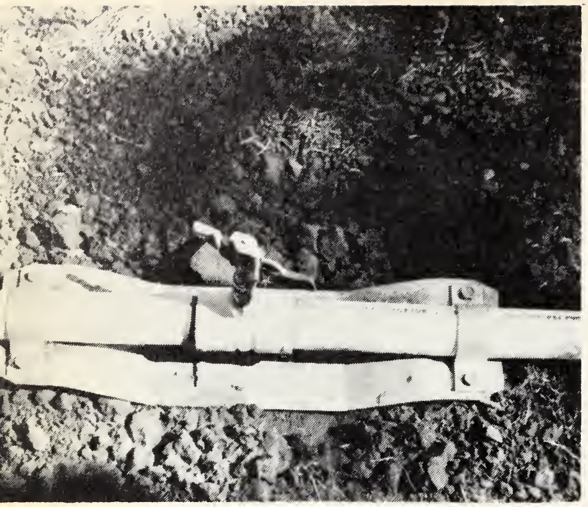
This system is the least costly to install and the most widely used of all sprinkler systems. When used in orchards, the pipe may be moved two tree rows placing the lateral lines in alternate middles for every other irrigation. Or for widely spaced trees, the lateral may be placed in every row center as the lines are moved across the orchard. The photo shows sprinklers in a prune orchard spaced at 30 feet along the lateral line. The lack of low hanging branches on the trees allows the water to be distributed uniformly to all parts of the orchard.

The portable sprinkler system shown irrigating the staked vineyard uses risers about 30 inches high so that the trajectory of the water passes above the untrellised vines. The sprinklers are spaced at 30 feet along the lateral. The lines are moved to

every fourth vine row, a distance of 48 feet. The water here is applied with a precipitation rate of 0.15 inch per hour, which applies 3.6 inches depth of water during each 24-hour set of the lines. Difficulty in moving the pipes across the vine rows generally precludes the use of portable systems in trellised vineyards.

Side-roll systems

Here, the pipelines are mounted on wheels so that the lines can be rolled laterally across irrigated pastures, alfalfa fields, or other low growing crops. A small gas engine with a chain drive connected to the pipe near the center of the lateral line supplies the power needed for rotating the wheels when the lines are moved. The pipeline serves as the axis for the wheels, and extra-strength aluminum pipe is needed to prevent damage due to torsion. The distance the pipe is moved for each setting is determined by the diameter and number of rotations of the wheels. This distance is usually 50 to 60 feet. The sprinklers are spaced 30 to 40 feet apart on the pipeline, and must always be in an upright position in order to distribute the water uniformly over the field.



End-drag systems

Pipelines are mounted on dollies or skids so that the pipe can be moved by towing with a small tractor or car. The mainline pipe, to which the laterals are connected, is placed through the center of the field. The lateral lines are moved alternately from one side of the mainline to the opposite side so that adjacent settings will be 50 to 60 feet apart. Such systems are commonly used in pastures and are also used in some orchards and vineyards. They are seldom used in row crops because the plants may be damaged by the moving of the lines.

Solid-set sprinkler systems

Portable aluminum pipe is used for the laterals with enough pipe so that a line can be placed every 40 to 60 feet across the field. Once the system is installed, no moving of pipe is required in order to irrigate the entire field; they are generally removed prior to harvesting the crop. Such systems may be used only during the germination and emergence period for vegetables and row crops. (See "Solid Set Sprinklers for Starting Vegetable Crops," AXT-294, University of California Agricultural Extension Service.) Or the system may be used during the entire irrigation season for potatoes, cotton, sugar beets, and other vegetable and field crops. Solid-set sprinklers are also used to provide frost protection for some orchards, vegetables, and field crops.

Hose-pull systems

Sprinklers attached to portable hoses are used for irrigating many orchards planted on steep lands. The hoses are usually ½ inch diameter flexible polyvinyl chloride plastic tubing in lengths not over 165 feet, which can be easily pulled when filled with water during moving of the sprinklers. One to three sprinklers spaced the same distance apart as the tree spacings are attached at the end of the hose. In order to prevent excessive hydraulic friction losses in a ½-inch hose, the total discharge of the sprinklers should not exceed about 2.25 gallons per minute (gpm). Thus, one sprinkler with a discharge of 2.25 gpm, or three sprink-

lers each with a discharge of 0.75 gpm could be used. A 0.75 gpm sprinkler placed at the intersection between four trees spaced 22 feet apart would apply 3.4 inches depth of water in 23 hours. This amount of water would satisfy the peak water requirement of most trees for a 10-day period. A single hose with three such sprinklers would serve a total of 30 trees, or two rows of 15 trees. Buried pipelines are used to deliver the water to faucets on risers to which the hoses are attached. These outlets are placed in a tree row at the center of the area served by each hose. The sprinklers are mounted on skids which keep them upright. These are moved by pulling the hoses which eliminates the need for walking on wet soils.

Permanent sprinklers

Buried pipelines are used for irrigating many orchards and vineyards planted on hillsides. They are also used for irrigating some pastures in the foothill areas. (See "Permanent Sprinklers for Hilly Pastures," AXT-n51, University of California Agricultural Extension Service.) Most systems use polyvinyl chloride plastic rigid tubing for the lateral and submain lines in sizes up to 4 inches diameter, and use plastic, asbestos-cement, or steel for the larger sized mainlines.

When these systems are used in vineyards, the risers with sprinklers extend above the vines. These are usually placed in every fourth vine row at every fourth or fifth vine in the row. These systems are used not only for irrigation but are often used for frost protection and cooling of the vines. (See "Frost Protection Costs for North Coast Vineyards," Leaflet AXT-267, University of California Agricultural Extension). Low precipitation rates (0.11 inch per hour) permits the use of relatively small pipe in order to keep the installation costs at a minimum.

Permanent sprinkler systems installed

in orchards generally use under-tree sprinklers. In citrus and avocado orchards with low, hanging branches, a sprinkler may be placed near the drip line of each tree. The sprinkler in deciduous orchards are generally placed between every other tree in every tree row on a diamond pattern. These under-tree sprinklers are sometimes used for frost protection, particularly in almond orchards. When operated continuously during the frost period, they will provide a 2° to 4° F temperature rise. A number of growers apply fertilizers with the irrigation water. Over-tree sprinklers attached to tall risers are used in some orchards for irrigation, frost protection, and cooling. Some crops are sensitive to sodium or chloride sprayed on the leaves; this suggests that water quality for over-tree sprinkling may be a limiting factor. The use of over-tree sprinklers for applying pesticides with irrigation water is currently under study.

Screens and filters

Where sand from a well or trash from canal water might plug the sprinkler nozzles, screens are used to clarify the water. The cylindrical screen on the pump discharge is used in conjunction with the hose-pull system which irrigates the young almond orchard. The screens on the side of the canal bank remove materials which might interfere with the operation of the permanent sprinkler system used for irrigating the almond orchard in the background.

DRIP IRRIGATION

A method of applying irrigations by releasing the water a drop at a time onto the soil from small orifices has attracted the attention of many growers. This method is now used on a number of avocado and citrus orchards planted on steep hillsides —and some deciduous orchards and vineyards planted on rolling lands in California. It is also being used in place of contour furrows for watering some strawberries and vegetable crops planted on steep land.

The requirements for drip irrigation are similar to those for other methods of irrigation. The amounts of water applied must be adequate to supply the water needs of the crop. Available soil water should be maintained in a major portion of the root zone. The application rate of water from the orifices should be consistent with the infiltration rate of water into the soil being irrigated.

The orifices may be devices, called emitters, with small openings the size of which controls the rate of water outflow—short lengths of plastic tubing 0.035 to 0.045 inch inside diameter, called "spaghetti," with the rate of outflow controlled by their length and diameter, or small perforations in plastic tubing with the rate of outflow controlled by the size and spacing of the openings. The water is delivered to the emitters or spaghetti outlets through plastic pipe or tubing, PVC or polyethylene, which can be laid on the ground surface or be buried. The pressure in the supply lines must be controlled within the ranges specified for each type of outlet. The orifices are designed for rates of water outflow varying from ¼ to 2 gallons per hour, and with recommended pressures ranging from 1.5 to 30 pounds per square inch.

On steep ground, differences in elevation cause pressure differences that materially affect emitter discharge rates, particularly those operating at low pressures. This will cause poor uniformity of water distribution. To avoid this, laterals must be nearly level and pressure regulators will be needed on the main lines.

This young avocado tree planted on a very steep hillside is irrigated by two emitters located on the uphill side of the tree. Water drips slowly from the emitters wetting the soil around the tree. As the tree grows larger, additional emitters will be required to supply moisture to the ex-

panding root system. The trees are planted 15 to 18 feet apart in rows that follow the contours of the hill. The tree rows are 20 to 23 feet apart down the slope. The ½-inch polyethylene tubing to which the emitters are attached is 200 feet long. The pressure in the lines is controlled at about 20 pounds per square inch. The water is filtered, and nutrients are added before it enters the distribution lines.

These staked tomatoes, planted in San Diego County, are irrigated with a "twin-wall" hose laid along the vine rows. The system contains an inner and outer hose made of thin wall polyethylene tubing. The outside tubing has perforations spaced at 18 inch intervals and the inside tubing has perforations every 72 inches. The perforations are 0.025 inch in diameter. Pressure is maintained at about 2 pounds per square inch, and about 16 gallons of water is released each hour to each 100 feet of row. Mature plants are irrigated twice a week for 4 to 8 hours, depending upon the need as indicated by soil moisture tensiometers. Lines up to 250 feet in length can be used. The water is filtered and nutrients are added before it enters the system.

This method permits irrigating row crops with saline waters which would injure the plants if sprinkling or furrow irrigation methods were used. The dripped water applied on top of the beds carries the salts in solution to the periphery of the wetted zone where it accumulates away from the main roots. If excessive amounts of salts do accumulate, it may be necessary to leach the soils with a sprinkler system following each crop.

Because the orifices used with drip irrigation are very small, the irrigation water must be screened or filtered to remove any particles which might plug the outlets. Slime caused by filamentous algal growth in the supply lines may cause plugging, and the lines should be flushed at weekly intervals. Some of the emitters are self-flushing when the water is first turned on. However, care is required to make sure that each orifice is operating properly at all times.

The photo above shows the "heart" of an elaborate drip irrigation system installed in a San Diego County avocado orchard planted on steep land. The system includes not only filters and a device for injecting nutrients into the water, but electronically operated valves that turn the water on and off as directed by soil moisture tensiometers located at strategic places in the orchard.

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